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AUTHOR Lefton, Lester A.
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ABSTRACT

This report summarizes four groups of experiments examining the nature of basic perceptual processes in reading. The first group examined the relationship of English orthography to reading, specifically the transfer of information from the icon to short-term memory. The second group of experiments examined the use of peripheral information extraction in the reading process. The third group looked at peripheral information as a function of retinal location. The fourth group looked at reading-disabled subjects and their eye-movement strategy when presented with a match-to-sample task. Overall, the studies support the notion of a peripheral-to-cognitive search guidance system in which subjects use peripheral information to a great extent. The older the subjects, the more they are able to use this peripheral information. When peripheral information is not provided, subjects do not do as well in whatever task they are provided. Reading-disabled subjects are not only unsystematic but are least likely to use this peripheral information because of their lack of a cautious, systematic strategy. (Author/AA)

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FINAL REPORT

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A DEVELOPMENTAL EXAMINATION OF BASIC PERCEPTUAL PROCESSES IN READING

LESTER A. LEFTON
UNIVERSITY OF SOUTH CAROLINA
COLUMBIA, SOUTH CAROLINA 29208

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INTRODUCTION

The purpose of the present experiments was to examine the nature of basic perceptual processes in reading. The studies were conducted in an attempt to examine the cognitive and perceptual processes that are involved in the act of reading, not in the process of learning to read. There is little doubt that those who are concerned with teaching reading will be able to use some of the data presented herein, but the studies were not intended to revolutionize applied reading specialists.

The general approach taken has been that of an information processing analysis. This technique has examined different aspects of the reading process in components, thus when studying English orthography certain parts of English orthography are studied. The aim of this series of studies was to examine several different stages thoroughly so that eventually a unified model of reading could be put together.

One of the critical components of all of the studies reported herein is that they are developmental. For complete understanding of reading it is necessary that we look not only at efficient adult readers but also at children who are learning to read. As one study will report (Section A.1), in a relatively brief period, children are able to handle complex English orthography and within a very short time they can essentially process any kind of reading material in much the same way that adults do. By using the same kinds of tasks at different levels the present experiments therefore examine to what extent children and adults process in the same manner.

Four basic groups of experiments have been published based upon the present project. The background of each of these groups will be discussed individually as will their overall results and implications for education. Methods, results, and conclusions will be presented within each of the four sections.

A. ORTHOGRAPHIC STRUCTURE

A.1 Orthographic Structure and Reading Experience Affect the Transfer from Iconic to Short-term Memory

Lefton, L. A. & Spragins, A. B. Orthographic structure and reading experience affect the transfer from iconic to short-term memory.
Journal of Experimental Psychology, 1974, 103, 775-781.

The extraction of information from briefly presented arrays and its subsequent encoding from icon to short-term memory has generally shown to proceed sequentially from left-to-right with adult subjects (Mewhort, Merikle, & Bryden, 1969). It is generally found that the

nature of this transfer is affected by the familiarity of letter strings, with sequences of letters that closely approximate English orthography transferred more rapidly than random strings. Indeed, Mewhort, et al., (1969) showed a more rapid transfer of familiar letter strings by presenting subjects with eight letter sequences of zero or second order of approximation to English. Processing time of the stimulus was controlled by varying stimulus duration and by the delay of the pattern mask. He showed greater accuracy with increased processing time. In addition, accuracy was greater for second order approximations than zero order. In another study, Keenan (1972) found evidence suggestive of left-to-right processing in English reading children and right-to-left processing in Hebrew reading children.

Overall, we find the ability to use orthographic structure had been found to follow a developmental pattern (Gibson, Osser, & Pick, 1963; Rosinski & Wheeler, 1972). An important question which was unanswered before the present project was the extent to which children and adults process items in a left-to-right or right-to-left manner. An experiment was conducted in which processing time was manipulated and the left-to-right variable assessed by differential masking of the left- or right-side of the array (Lefton & Spragins, 1974).

Method, Experiment I. Subjects were 1st, 3rd, and 5th graders from local school districts. They were presented with eight item pseudowords chosen from lists provided in the experimental literature that were either fourth order approximations to English or first order approximations. The child was told that he was going to play a game and that initiating a trial by pressing a button, stimuli would appear for a brief time. The sequence of stimulation was fixation point followed by a pseudoword and a mask and then back to fixation. The pseudowords were presented for 50, 100, 150, 200, or 300 msec; the mask was presented for 200 msec.

The purpose of the experiment was to examine the nature of processing and the transfer of information from iconic to short-term memory. To that end, of course, it was necessary to control the amount of time that letters were processed within the icon. Thus, a mask was used to control processing time with manipulations of stimulus durations.

Results. Overall, the results showed that with increased processing time all subjects did better. Indeed, all of the main effects (Grade, Order of Approximation, Processing Time, and Serial Position) were significant. In the first portion of this experiment when processing time was manipulated, it was shown that given more processing time subjects were able to process more letters, but accuracy on the left was greater than accuracy on the right and that there was a processing time by order of approximation interaction. The data is suggestive of a left-to-right sequential processing mechanism.

Method, Experiment II. In a second experiment the first experiment was repeated but only half of the array, either the left-half or the right-half, was masked. When the left-half of the array was masked accu-

racy on the right should be lower than when the left-half is not masked. But, accuracy on the left should not be affected when the right-side of the array is masked. These predictions are based on the notion that subjects transfer information from the icon serially, item by item, from left-to-right and masks on the left disrupt the entire processing sequence, whereas masking on the right may disrupt accuracy on the right, but not affect accuracy on the left.

Results. The results support this basic contention. They suggest a serial processing strategy. In both experiments there was greater accuracy of report on the left four positions than on the right four positions. In addition, the position effect interacted with grade level and duration, and order of approximation indicating that the longer the stimulus is available, the older the child and the higher the order of approximation, the more efficient left-to-right processing proceeds.

The results of the study support a model of the transfer of information into short-term memory that is sequential when operating in a left-to-right manner. Many tachistoscopic experiments involving word and letter recognition have generally been conducted to make inferences about reading. Tachistoscopic tasks resemble reading in that they present single words for brief durations; a single fixation in reading must last at least 200 msec, thus there is a similarity between the two tasks. Although reading is clearly not a letter-by-letter process the stimulus for reading is words.

Conclusions. Overall, this study showed that the processing of letter strings proceeds sequentially from left-to-right. Further, processing proceeds more rapidly for orthographically constrained pseudo-words than for random string. Last, processing ability was found to develop during their early school years with changes essentially complete by about the third or fourth grade level.

A.2 Probing Information From Briefly Presented Displays of Alphabetic Material

Lefton, L. A. Probing information from briefly presented arrays. Journal of Experimental Psychology, 1974, 103, 958-970.

In the same manner as the Spragins and Lefton study (1974) a question of great concern is to what extent the extraction of information from the icon and its subsequent encoding into short-term memory proceeds in a left-to-right manner. In five probe experiments familiarity was manipulated by using first and fourth order of approximations to English as stimuli. Item-by-item, left-to-right, search behavior would be supported by high accuracy or short reaction times, on the left-side of the display, with decreasing accuracy or increased reaction time on the right-side. Evidence for scanning due to familiarity as defined by Mewhort, et al., (1969) would be shown by an interaction of the level of familiarity with spatial position of the letters or an increasing difference in accuracy or reaction time between familiar and unfamiliar

arrays from the left to the right side of the display.

Methods and results. Five probe experiments were conducted to investigate this phenomena. The first two experiments used spatial single item bar marker procedure. In Experiment 1 the stimuli appeared and were followed by a bar marker either above or below one of the seven letters. The subjects task was to identify the item indicated by the marker. In Experiment II the major manipulation involved a delay of the probe. The aim of these studies was to assess, in part, where the probe task can provide evidence for familiarity effect and if the effects obtained can be associated with sequential scanning.

The results of these two studies corroborated the existance of a difference due to familiarity as found in other studies and the effect of the delay of the probe. However, the difference in accuracy to familiarity was considerably smaller than in a free recall study. These two experiments, therefore, provided evidence to suggest that there is a small but reliable effect of familiarity of the stimuli although the effect can probably be attributed to guessing and although its size is small it does not vitiate the effect of familiarity but rather suggests that subjects use contextual information whenever it is provided. This is the same conclusion that was supported in part A.1.

To further investigate probing and the effect of familiarity subjects were put in a situation in which they had to respond with a reaction time measure and proceed through a number of items until they could find the critical target. Although the task requirements are clearly very different from these first two experiments, the level of processing at which the test takes place is still before short-term memory and thus at the initial stages of processing. This was done in three separate experiments using a variety of experimental manipulation. The results show that search for a critical target proceeds item-by-item and generally from the left-hand side of the display to the right-hand side. In some cases, search through arrays of familiar sequences was faster than through unfamiliar sequences. These data further suggest that when subjects are given the opportunity to search and process letter arrays in any manner unconstrained by the experimental task, they do so from left-to-right rather than from right-to-left or ends-to-middle.

Conclusions. Taken together with the results presented in Section A.1, we are able to conclude that the processing of briefly presented arrays in adults who have had years of experience with English proceed in an orderly fashion from left-to-right. Even with central fixation which logically allows for central processing first and the equally likely alternative of ends first processing subjects proceed from left-to-right. Not only is the processing directional but it is also sensitive to the contextual constraints at the stimuli. When provided with familiar English orthography subjects use it to whatever extent possible. This finding is important because the recognition of briefly presented arrays can be used to assess both visual functioning and in the training of reading.

The educational implications of using more highly constrained stimuli may be a technique that may be used to aid teachers of reading when tachistoscopic tasks are employed. While the use of tachistoscopic tasks is probably not a good one, they are used to a great extent in the public school systems and in reading clinics. If they are to be used, the use of orthographically constrained stimuli is probably a good idea. This will become particularly evident in Section A.3 where English orthography was manipulated to assess the extent to which children use English orthography.

A.3 English Orthography: Relation to Reading Experience

Lefton, L. A., Spragins, A. B., & Byrnes, J. English orthography: Relation to reading experience. Bulletin of the Psychonomic Society, 1973, 2, 281-282.

The study of the nature of processing within short-term memory has shown that there exists a familiarity effect which is not due to mere guessing. Mewhort showed adult subjects eight item pseudowords varying in order of approximation and then asked them to guess the missing item (Mewhort, 1970). Mewhort showed that the higher the order of approximation the better subjects did. Lefton (1973) has recently replicated the results reported by Mewhort and has further shown that the duration of the stimulus presentation is irrelevant. A logical prediction based upon the results of Lefton would be that the extent of a person's experience with English should in part determine the nature of the obtained results. Children with varying amounts of formal training with English provide a concise test of this prediction. It was hypothesized that children with more formal training with English would be able to guess missing items with a greater accuracy than children with less formal training. To test these hypotheses children with three training levels were presented with pseudowords with an item missing and asked to guess its name.

Method. Three groups with ten children each were used as subjects and were presented with pseudowords which were either first order of approximations or fourth order of approximations to English. On each stimulus card one of the seven letters was replaced with a dash. The subjects were shown the stimuli repeatedly and asked to guess the name of the item that was missing.

Results. The number of correctly reported items was computed for each experimental condition for each subject and entered into an analysis of variance (Grade Level X Order of Approximation X Left vs Right). All main effects and interactions were significant.

The results were straightforward in that children with more formal training in English showed a greater accuracy for fourth order of approximations to English than first order of approximation. Children in Grade 1 with relatively little formal training were not able to make better guesses as to the missing item from the fourth order of approxi-

mations relative to first order of approximation. By contrast, third grade children showed dramatic increase in accuracy for fourth compared to first order of approximations, and fifth grade children showed still greater accuracy.

Conclusions. The use of English orthography and the developmental effects obtained are most reasonable. Both children and adults show low levels of accuracy with first order of approximations to English. Here there are no sequential constraints, each letter is independent of the next. By contrast, fourth order of approximation provide a great deal of context and accuracy should increase for people with knowledge of English orthography. This was precisely the case.

As suggested in A.2, the use of English orthography in training and assessment can be very important. Few people have realized how much English orthography is important in the reading process although this is changing. In a recent review by Krueger (1975) the use of familiarity in the recognition of letter strings and in reading has been assessed. The present results were largely substantiated.

B. SPATIALLY TRANSFORMED TEXT AND ITS IMPLICATIONS FOR PERIPHERAL INFORMATION EXTRACTION IN READING

B.1 Eye Movements

> Spragins, A. B., Lefton, L. A., & Fisher, D. F. Eye movements while reading and searching spatially transformed text: A developmental examination. Memory & Cognition, 1976, 4, 36-42.

One of the most interesting theoretical notions that has developed over the last few years has been a peripheral-to-cognitive search guidance model. Originally proposed by Hochberg (1970) this model suggests that both adults and children are relying upon the periphery for physical feature cues. When the critical feature information is detected, a saccadic eye movement is initiated so that subsequent foveal processing can occur on higher information areas. The higher level in interrogation, the cognitive search guidance, is responsible for meaning extraction preprogramming the visual system for subsequent high information physical features. The difference in the speed of processing between reading and visual search suggests that reading requires a greater involvement of the cognitive search process meaning extraction, whereas search is primarily dependent upon the visual periphery. According to this peripheral-to-cognitive search guidance model, when spatial cues are distorted this should modulate the speed by which readers and searchers go about their task. When Smith (1969) and Smith, Lott, and Cronnell (1969) examined word shape change they found that reading and search efficiency were reduced significantly. Similarly, Hochberg, Levin, and Frail (1966) found that the eye-voice span was reduced in oral reading

efficiency was disturbed when spaces were filled between the words in textual material. Hochberg has interpreted these data as indicating that filling the spaces interrupted peripheral cue accessability leading to a strictly foveal input of the stimulus material. A study was conducted for eye movement with reading and search in children and adults where typographical manipulations of word shape and word boundaries were made. A developmental examination was undertaken to aid in determining the level at which these spatial cues become important factors in efficient reading. Three grade levels, 3rd, 5th, and adults were used to examine the developmental progression and ocular-motor efficiency in the task of reading and search.

It was hypothesized that the disruption of spatial cues would force experienced readers to resort to less efficient strategies like that used by inexperienced readers. The data have both applied and theoretical importance because information from the peripheral is necessary for efficient reading and search. With perturbed word shape and word boundary of the information in the periphery is destroyed.

Method. Children of the 3rd, 5th, and adult levels were used as subjects. The stimuli were paragraphs standardized within a grade level with difficulty but varying between grade level for difficulty and length. There were different paragraphs at each grade level. The stimulus paragraphs were typed with variations of spacing and case. There were three levels of spacing and two levels of case. In a normal spacing condition there was one typewritten text. In the filled spacing condition, spaces between words were replaced with +'s. In the absence spacing condition, the spaces between words were eliminated altogether. In the normal case condition, upper and lower case letters appeared as normally typed. In the alternating case condition upper and lower case letters alternated through the paragraphs as shown in the following phrase. "ThE bIg BoY." The three spaces and two case conditions were factorially combined. Eye movements during reading and search were monitored by an Eye-Trac and both forward going saccades and regressions were examined.

Results. A large volume of data were collected for both reading and search. Measures of frequency of fixation, fixation duration, and regressions were all examined.

The experiment compared developmental changes and has shown that experienced readers examined larger units of information but paused for shorter durations during each fixation than inexperienced readers. The experience of adults seems to enable them to switch strategies from a large unit type of processing to a nearly letter-by-letter-like processing with disruption of spatial cues.

The loss of spatial cues is detrimental to both reading and search even though the spatial cues appear to be used somewhat differently in the two tasks. One possible means of accounting for this difference is to assume that there is a limited capacity processing. During reading,

processing is dependent upon comprehension demands as well as physical feature input. As the spatial cues become increasingly more perturbed processing efficiency deteriorates. By contrast, during search, there is very little demand for comprehension because only physical features need to be detected. Search, therefore, operates in an all or none fashion and is dependent upon the availability of distinct cues. In reading, the loss of peripheral information leads to a letter-by-letter-like processing. By contrast, in search the loss of peripheral information only leads to a decreased unit size of processing; the unit itself remains at about 2 1/2 to 3 characters.

The complimentary nature of graphic and contextual cues contributes to an overall increase in the perceptual span of readers which is dependent upon experience (c.f., Rayner, 1975). The role of contextual information and spatial information varies not only with experience but with an individual reader's adopted strategy. Adults, in both reading and search, tend to be more dependent upon spatial cues than young children, whereas all subjects are reduced to a nearly letter-by-letter-like processing technique when spatial cues are highly perturbed. The cues of word shape and word boundaries differ in importance in reading and search. Children compensate for differing task demands by taking in fewer letters and making fewer but longer fixations during reading and search. Adults, on the other hand, remain fairly constant in fixation duration and number of fixations and simply increase recognition span from reading to search.

Conclusions. This eye movement study has shown that the Hochberg model of peripheral to cognitive search guidance can account for large bodies of data because when all spatial cues were unavailable all subjects resorted to a letter-by-letter-like strategy process in reading but not in search. Although reading and search were found to be sensitive to the same types of spatial manipulations, discrepancies of span and speed suggest qualitative differences. It is most likely that comprehension demands to reading can account for these differences.

B.2 Peripheral Information Extraction Continued

Fisher, D. F. & Lefton, L. A. Peripheral information extraction: A developmental examination of reading processes. Journal of Experimental Child Psychology, 1976, 21, 77-93.

A study was conducted which was an extension of the eye movement study reported in B.3. The goal was to further substantiate the notion that adults and children use peripheral search guidance in which physical feature cues are detected. A subsequent cognitive search guidance in which saccades are initiated to bring relevant cues and features into the fovea is the second portion of the model. Three experiments were conducted. The first one examined the effect of word shape and word boundary on reading speed. The second study examined the same manipulations in a paragraph search task, and a third study examined search

in a tachistoscopic task in which peripheral information was spread across the visual field in varying degrees.

Method, Experiment 1. This experiment was a psychophysical study which examined reading speed much like the study by Spragins, Lefton, and Fisher (1976). Three kinds of case were used: normal, capitals, and alternating. There were three spacing conditions: normal, filled, and absent. The subjects were to read short paragraphs and answer some questions so that they would read rather than skim. Basically, the design was similar to the study by Spragins, et al., (1976).

Results. All main effects and interactions were significant. When word boundary and word shape information was degraded reading became more like a letter-by-letter or word-by-word process than one in which larger units of information are processed. When word boundary or shape was degraded reading would slow down. This effect is important and will be discussed after Experiments II and III.

Method, Experiment II. Essentially the same experiment was repeated again with search. It was hypothesized that foveal input reduced subjects to reading in a letter-by-letter-like process, whereas in search where comprehension demands are limited, such a process might not be as exaggerated.

Results. Speed and errors were analyzed for search data. As before, all the main effects were significant. As the subject's grade increased so did his ability to search the paragraphs more quickly. Third grade children searched at an overall rate of 130 words per minute. Grades four and six and adults searched at 225, 263, and 324 words per minute, respectively. All of the subjects relied on cues. While adults were able to search up to three and a half times faster in a normal case space condition they were reduced to a similar search speed as the young children when word shape and word boundary cues were degraded.

Conclusions. The overall differences in speed between reading and search can probably be attributed to the differences in the degree to which meaning extraction is required. By degrading word shape and word boundary, subjects were probably thrown into a "tunnel vision" situation. This is most likely caused because of the limited ability of the perceptual system to extract information from degraded visual arrays. Again, Hochberg (1970) has hypothesized a developmental progression of word boundary and cue extraction efficiency which seems exemplified by the present data. The data showed increases in performance decrements with increasing experience with English text. Taken together, the results suggest that the functional field of view during a fixation varies depending on many cues provided, the task demands, and the experience with English text.

Method, Experiment III. Another way to examine the peripheral and foveal components in information extraction task is to vary the size of the visual field and age in a tachistoscopic recognition task. This

was done in a series of experiments reported by Lefton and Haber (1974) and will be reported in greater length in Section C.1. The same essential design was used in the present study and done developmentally. The ability of subjects to respond in a same-different task was assessed as a function of visual field, retinal location, and response type of same or different. This study was a replication and extension of the work by Lefton and Haber (1974, see Section C.1). A developmental examination was undertaken to investigate the possibility that cerebral dominance is a developing aspect of the information processing system with changes in the left-right dominance as a function of age. For example, it has been shown that children have a narrower visual field of view (Lakowski & Aspinall, 1969), thus childrens same-different responses might not only take longer, but there may be an interaction of Age X Retinal Location. On a theoretical level, these results have important implications for studies of peripheral information processing. We have argued in Sections B.1 and B.2 that dependence upon physical feature extraction increases with age and subsequently affects eye movement patterns. If this is indeed the case, adults and children should differ in their peripheral information extraction capabilities. Therefore, a tachistoscopic examination was made between subjects as a function of age and visual field extent.

Adults and children in 2nd, 3rd, and 5th grades served as subjects. They were presented with a pair of vertically arranged letters on a screen either to the left or right of fixation varying from 1.3 to 4°. There were seven possible retinal locations, three to the left and three to right plus fixation. There were equal numbers of same-different combinations and the subject's response was a reaction time as to the sameness or difference of the letter.

Results. There were strong effects of grade and retinal location and a significant interaction between grade and retinal location. Reaction times were markedly increased with decreases in grade level. A Retinal Location X Same-Different interaction showed that sames were faster in the fovea and differents were faster in the periphery. This is the same interaction that was found in the study by Lefton and Haber (1974). There was no effect of visual field of presentation. Information presented to the periphery was far less discriminable for the children than for adults. This finding is important because performance measures in totally different tasks (Experiments 1 and II of the present series) now become linked and can be interpreted in terms of peripheral visual processing.

Conclusions. Children have a reduced perceptual span and are expected to read slower than adults. Degraded peripheral cues should cause children to have at least a minimal decrement in speed, while adults would become highly dependent upon peripheral cues and should be forced to slow up even more dramatically. This was indeed the case and the data from this third experiment replicates the results reported by Lefton and Haber (1974). Second, there is no effect of visual field of presentation. Third, children take more time to respond to judgments

of sameness or differents than adults. Fourth, and most important, information extraction in the periphery for children is poorer than for adults and in accord with the interpretation of reading and search experiments (Sections B.1 and B.2).

Overall summary. The peripheral search guidance to cognitive search guidance mechanism proposed earlier accounts for all of these data. The visual periphery picks up cues and features from printed text but does not analyze them for linguistic content. This is the role of higher order cognitive search guidance. Data from the present experiments further delineate the first stage activity of this two-stage process. The data can be interpreted as demonstrating the efficiency by which the periphery processes physical feature information. Bouma (1970) and McConkie and Rayner (1975) and Rayner (1975) have described the limits of peripheral sensitivity in terms of acuity and estimates of the maximum span of perception. These estimates approximate 4° or about fourteen letters around the center of fixation. We have shown in the study by Spragins, et al., (1976, Section B.1) that the size of the perceptual span is dependent upon the contextual demands involved, namely reading and search. Taken together, the mechanisms are available in the visual system to affect the initial screening state.

The model proposed by Hochberg (1970) does not account for all of the data, however, it is the most parsimonous model to date. It further allows the practitioner and the reading theorist to investigate the possibility of teaching the new reader how to use the periphery to a greater extent and thus efficiently use all mechanisms available to him. When teaching a child to read peripheral information processing should be stressed, not only foveal input gathering mechanisms.

C. INFORMATION EXTRACTION FROM DIFFERENT RETINAL LOCATIONS DURING SEARCH

C.1 Information Extraction from Different Retinal Locations

Lefton, L. A. & Haber, R. N. Information extraction from different retinal locations. Journal of Experimental Psychology, 1974, 102, 975-980.

There is a long rational to a series of four experiments which examined manipulations of retinal locations in visual field of presentation and the response variables in a visual matching task. Indeed, the range of variables which affect the information extraction as a function of retinal location is very wide. There are many differences between procedures and tasks. However, a basic reason for examining such data is that the ability of subjects to extract information as a function of retinal location converges directly upon the question of to what extent people are able to extract peripheral information in reading.

Method. A series of four experiments were conducted in which the

subjects had to classify a pair of vertically arranged letters which were briefly presented as same or different. The pair could appear in one of the 11 retinal locations varying up to 4° on either side of the fixation point. This arrangement permits for an examination of the main effect of retinal location and a possible interaction between eccentricity and type of response (same or different or visual field, left or right). In one of the experiments upper case and lower case letters were always paired; the subject was required to make a name match rather than a physical match thereby permitting assessment of this variable. One experiment compared the traditional reaction time procedure of using two response keys with that used by Egeth and Epstein (1972) in which the subject used only one button.

Results. The main finding of the present experiments was that a change in reaction time was associated with a change in retinal location. The first experiment showed that with increases in retinal eccentricity from fixation judgments of sameness and differents required more processing time. The data provide evidence for a change in processing strategy depending upon the locus of stimulation. The Same-Different X Retinal Position interaction shows that at near foveal position same responses are faster than different responses; this is a result that has been found many times. As retinal eccentricity increases, however, the different responses come to be faster than the same responses. These results, the obtained interactions, and trend analysis support the conclusion that the subject's strategy may shift to a criterion of sameness or differents as a function of location of stimulation.

Conclusions. Overall, the results of the study show that when subjects are engaged in the visual matching task performance is slower the further the stimuli are from fixation. Two, there is a change in the speed of responses for same responses compared with responses compared with differents close to the fovea. Three, there is no difference between judgments of sameness or difference with respect to visual field of presentation. Four, the only hint of a visual field effect appeared when the subjects were forced to name the stimuli. And, five, neither spacing arrangements or response cue arrangements seem to exert a critical influence on the results.

C.2 Information Extraction During Visual Search

Lefton, L. A. & Fisher, D. F. Information extraction during visual search: A developmental progression. Journal of Experimental Child Psychology, 1976, 22, 346-361.

In Sections B.1, B.2, and C.1 it was suggested that the use of the periphery is very important in reading and visual search. Indeed, these studies have gone to great length to show that the extent to which the periphery is used is a function of age, experience, type of material, and the extent to which the information is available in terms of degradation. In this study, five visual search experiments were conducted.

In the first two, search speed through lists or paragraphs was manipulated when context was available or not available. A third experiment examined within item context predictability effects on search speed. The fourth and fifth experiments examined search developmentally when the amount of material was varied.

Method, Experiments I and II. Adults and third graders served as subjects in these experiments. The stimuli were either lists of words or paragraphs of words in which the words were presented in a normal meaningful sequential contextual flow, or in a scrambled order. Paragraphs, either normal or scrambled were typed left-to-right; lists, either normal or scrambled, were typed in columns of one word widths, two columns per page. Both paragraphs and lists contained the same words in the same order. Target words were chosen and the subject's task was to search for a critical target word. Each target word appeared only once in a paragraph. The basic difference between Experiments I and II was that one was a between-subject design and the other was a within-subject design.

Results. Each subject provided reaction time measures and error rates. Error rate was low. The reaction time results show that adults search speed is dramatically reduced in the presence of meaningful context, only if the context is within paragraphs. For children, there is little or no difference due to the type of material or context. The marginal nature of the significant main effect of type of materials can probably be attributed to the very slow but consistent search rates of the 3rd graders regardless of type of material. Clearly, adults searched differently through paragraphs and lists, whereas this was not the case with children. This difference was supported by subsequent and separate analysis of variance when the simple effects of children and adult data were examined.

Conclusions. These results support the notion that processing of textual material can be very rapid if there is no necessity for subjects to attend closely to the meaningful context. The periphery has been hypothesized as being a physical feature locating mechanism. The high search rate in a scrambled paragraph condition exemplifies a relatively pure analysis of peripheral visual processing. When context is present in the paragraph it appears that it is nearly impossible for adult subjects to avoid it, even though they are searching much faster than they could read it. Children seem to be operating on a decoding or features level and are not affected by meaning to any real degree. Such a notion of sharing of processing capacity to analyze features and meaningful context even during search is intrigueing. Peripheral processing efficiency is reduced with the addition of meaningful context and slow down overall search rate. In list search conditions on peripheral information is available and thus each item must be handled independently; this leads to low contextual awareness, and both types of material are processed at equal rates.

Experiments I and II provided evidence that target search time for

adults was dependent upon the presence of meaningful context. This has been shown in other studies, for example, that by Krueger, et al., (1974). Similarly, Brand (1971) and Ingling (1972) had subjects search through lists of letters and numbers in which the target was either a letter or a number. Both Brand and Ingling have interpreted their results to suggest that subjects are able to make discriminations about the class of information through which they are searching independent of identifying their names of the background letters. The present experiment explored the possibility by partially replicating their results and extending them developmentally.

Method, Experiment III. The subjects were 3rd graders, 5th graders, and adults. The stimuli were lists of letters or numbers in which the target was either an X or the number 7. The lists contained only one X or one 7. There were four conditions which were a factorial combination of the two types of lists (letters or numbers) and the two types of targets (X or 7). These four conditions were tested on each subject with each subject receiving nine trials on each of the four conditions.

Results. Each subject provided one search time measure for each position for each of the four conditions. With a low error rate the search times were entered into an analysis of variance with all of the main effects and interactions being significant.

Conclusions. These data are interpreted as favoring the possibility that sensitivity to within item context increases with experience if confounds arising from the familiarity of the stimulus array are controlled. Since search through lists in Experiment III were shown to be sensitive to meaningful material a variable which has remained relatively unexplored is the amount of material through which subjects search. This was the focus of Experiments IV and V.

Method, Experiments IV and V. Third graders and adults were asked to search through lists of letters which were either one item wide or two, three, four, five, six, seven, or eight items wide. They were presented with nine trials at each list with order of conditions being randomized.

Results. Overall, the results with a low error rate showed that adults can search faster than children and as expected search times increased significantly as a function of position. The systematically increasing slopes that were found show further increases when the children search and was supported by the three-way interaction of Grade X Position X Width.

Conclusions. These data provided direct estimate of the perceptual span as a function of developmental level. It can be seen that 3rd graders handle a two item list with about the same efficiency with which adults handle four items. These data possibly provide a direct estimate of the perceptual span of each grade level. Estimates of the immediate perceptual span show four to eight items (see Section B.1). If the amount

of information in an item exceeds the perceptual span a saccade must be initiated so that the additional information can be viewed. The amount of new information is also limited to four items for adults. Evidence for this notion is presented by a lack of a difference of slopes with curve over the widths five through eight.

Overall summary and conclusions. Experiments I and II examined search rates and subjects were presented with either lists or paragraphs that were either context or scrambled. These two experiments showed that meaningful material and contextual information in the periphery was able to modulate search speed. In Experiment III a developmental examination of within-item predictability was examined and showed slower search rates for 3rd graders compared to adults, a significant difference between the children. Experiment III showed that between-item or within-item effects modulate search speed. Thus, search speed is dependent upon developmental level, type of information, how the information is provided. In Experiments IV and V, the effect of increasing list width on search time was examined. Overall, the results showed a developmental progression with list width increasing the search time necessary to find their target. The data were interpreted as demonstrating that once again, perceptual span for children is significantly smaller than those for adults. Such an interpretation of these data may be directly applicable to increasing dependence upon the visual periphery in locating relevant gross physical features essential to the development of reading skills. When no gross physical features are available masking of the letters or some other phenomenon would account for the tunnel vision effect. With tunnel vision effects occurring, additional saccades must be made to compensate for reducing peripheral receptual span.

These data support other data from our laboratory (Sections B.1 and B.2). Taken together, these results suggests the small functional field present in young readers probably inhibits efficient processing of successive cues and features. This functional visual field is probably the most limiting aspect of slow young reader performance. Any theoretical model of reading performance that precludes linguistic cues and features as being more important than basic visual cues and features seems to be inadequate.

The results of thes five experiments are interpreted as providing support for a model in which peripheral information and context play an important role in search. Hochberg (1970) has suggested such a model in which the periphery picks up cues and physical features in such a manner and which direct subsequent eye movements (peripheral search guidance) and higher order processing (cognitive search guidance).

D. READING DISABILITY: THE DISCRIMINATION OF LETTER COMBINATIONS

D.1 Discrimination of Letter Combinations in Good and Poor Readers

Lahey, B. B. & Lefton, L. A. Discrimination of letter combinations in good and poor readers. Journal of Special Education, 1976, 10, 205-210.

A very different focus of the present project has been to examine the notion of perceptual deficits and the ability of adults and children to examine and discriminate letters. In this study, good and poor readers were presented with a match-to-sample letter discrimination task.

Method. Children in the 2nd, 3rd, and 5th grade who were in either the upper portion of their class or in the lower portion of their class served as subjects. They were presented with single letter items or items that were two, three, four, five, six, or seven letters in length. They were tested several times in an untimed situation from which they had to choose one of seven alternatives as the correct one to match to the sample.

Results. The results suggest that children make more errors on match-to-sample problems composed of several letters than on those composed of one letter or a few letters. In addition, poor readers appeared to make relatively more errors than good readers on longer items.

Conclusions. Since this experiment was conducted using stimuli and time conditions more like natural reading conditions than previous studies, these results suggest that deficits in visual discrimination may, in fact, play an active role in reading problems of elementary school children. The decline in the number of errors associated with increasing grade levels indicates less importance over age, but persists through the second grade and probably into the third grade. It's possible that a procedure such as this may have some utility for the presentation of reading materials to poor readers. This possibility is explored in greater detail in Section D.2.

D.2 Eye Movement Strategies in Normal and Reading Disabled Children: An Analysis of the Ability of Poor Readers to Discriminate Letters

Lefton, L. A. Eye movement strategies in normal and reading disabled children. Paper presented at the symposium, "Eye Movements in Psychological Processes II", Monterey, California, February 6-9, 1977, sponsored by Behavioral Research Directorate, U.S. Army Human Engineering Laboratory, Aberdeen Proving Ground, Aberdeen, Maryland

Lefton, L. A., Lahey, B. B., & Stagg, D. I. Eye movements in normal and reading disabled children. Manuscript submitted for publication.

Using the same basic design as the experiment reported in Section D.1, an eye movement study was undertaken to investigate the strategies of normal and reading disabled subjects. One motivation for the study was to replicate previous results with reading disabled children. A

second motivation was to examine the frequency of fixation of disabled children compared with normals. Third, and perhaps the potentially most important, was the concern of assessing the ability of using eye movements to validate a theoretical position and to evaluate the possibility of using eye movements in a match-to-sample task as a diagnostic tool. Eye movements can be a powerful diagnostic tool in assessing reading disability and this possibility is explored at greater length.

Method. The subject pool consisted of 24 subjects at each of four grade levels, 3rd graders, 5th graders, and adults. There was also a group of reading disabled children who are age-matched with the 5th grade. The reading disabled were defined in a traditional way. They were children who had scored normally on intelligence tests, had no sensory defects, but who were performaing a minimum of 1 1/2 to 2 grade levels behind their age-matched counterparts.

All of the subjects were presented with the same match-to-sample stimuli. They were typed upper case letters in which a sample was typed on the left-hand side of a card and four alternatives typed horizontally across the card. The subjects were seated in front of a Biometric Eye-Trac machine which uses a photoelectric principle to measure eye movements. They were told the nature of the task and asked to locate the alternative which looked exactly the same as the sample on the far left. Four grade levels were tested using the same stimuli with four correct positions. Each of the 24 subjects at each of the four grade levels was tested three times at each position. Thus, at the end of the experiment there were seventy-two trials at each of the four possible positions for each grade.

Results. Scoring consisted of counting the number of fixations made per trial and a measure of the duration of each fixation. To summarize these data the frequency data showed that the adults looked less frequently than the children to make the correct decision and that the reading disabled group made the greatest number of fixations. The duration data showed that the younger the subject the more time he spent; however, the reading disabled child behaved similarly to their age-matched counterparts. Thus, the reading disabled group was spending about the same amount of time as the other children their age on a fixation yet they were looking more often. Intuitively it might be expected that they might be expected to look more often but look for less time, essentially just taking a quick glance. Neither possibility was realized, they looked for about the same amount of time as their age-matched counterparts.

Overall, these results show that the reading disabled group was spending about the same amount of time per fixation as the 5th graders, looking more often by 25% yet making twice as many errors. To measure the efficiency by which the subjects were examining the stimulus array an analysis was undertaken of the sequence of their eye movements. On each successive fixation it was recorded where the subject was looking, that is, whether he was looking at the Sample, at the 1st, 2nd, 3rd, or 4th alternative. The volume of the data generated by this analysis was

enormous. To summarize, it was found that young children looked more often for more time in a relatively conservative manner in their search strategy. Adults looked less often, spent less time per fixation, but they too adopted a systematic approach. The reading disabled group is the most interesting for they looked more frequently than anyone else although they did not spend more time than their age-matched counterparts. Yet, the sequence of fixations of the reading disabled made was neither conservative nor systematic. They examined all of the alternatives in an nonsystematic manner.

Conclusions. The lack of a systematic search most likely brought about the higher error rate for the reading disabled subjects. Unlike adults, the children are being conservative, they are going back to the Sample after each trial to check to see if the Sample matched the alternative. This is consistant with our knowledge of the visual memories of young children.

It is important to note that the reading disabled subjects were making 13% errors, twice as many as their age-matched counterparts. Clearly, they were doing something wrong. Yet, they were making 87% correct judgments. They were able to discriminate letters and most of the time to be correct in their match-to-sample. The notion of a perceptual deficit, if it is at all valid, should not refer to the ability of a child to be able to make fine visual discrimination.

The conclusion of this study, therefore, is that reading disabled subjects are unsystematic and make more errors, they are not cautious, not conservative, and do not have adult memory spans. Thus, they adopt a hit or miss approach. Their problem is that they miss too often and have to make more fixations to achieve a modicum of success. We can use eye movements to assess reading disability, we can use eye movements to assess progress in teaching disabled to be more systematic. Since eye movements are largely under voluntary control they may be a natural component of behavior to modify the reading disabled. This is not a claim that eye movement training is going to fix the reading disabled, but systematic eye movements are a start in looking at remediation. Whether eye movements will be the answer to reading disability is unclear. It is probably unlikely. However, we can train more systematic cognitive control over eye movement strategies.

OVERALL CONCLUSIONS AND SUMMARY

A large number of experiments had been conducted to investigate a variety of perceptual processes involved in reading with both children and adults. Each of the sections contained presents a summary and conclusion section, often with educational implications. Many of the conclusions are tied to specific experiments; but, it seems appropriate to discuss the important role of peripheral information processing in reading.

Peripheral information processing is critical in reading. Few researchers, educators, and practitioners have considered the role of peripheral information processing. In the past, the role of the periphery has been acknowledged in that it might be necessary for efficient reading, yet, the present experiments show that the role of peripheral information is cruicial to reading. Adults, and to some extent children, use the periphery in reading to a much greater extent than thought before. This was shown most dramatically when peripheral information was destroyed by alternating word-case and word-shape. When this was done, subjects were reduced to a letter-by-letter-like reading strategy thus forcing a tunnel-like vision.

Efficient reading involves the extraction of information not only from the fovea but from the periphery as well. When teaching a child to read we do not want to just stress foveal letter identification, but also peripheral information extraction. In teaching a child to read we do not want to stress just letter identification or even word identification but rather we wish to stress that he identify groups of words together.

The limiting aspect of reading speed is determined by the number of fixations that an individual makes when reading. Clearly, if a subject is fixating on each word, or even twice on each word, his reading speed is going to be less than 300 words per minute. A normal adult reader can make about 210 fixations per minute. If he looks at one word for fixation his reading speed is limited to about 300 words per minute. To increase reading speed we have to look at more words per fixation. Similarly, to help a child read better or read more words per fixation the role of periphery must be stressed.

Taken together, the results of the present study show that the role of the periphery is not only crucial to normal adult reading but also in the teaching of reading. Teachers of reading must stress the role of peripheral information extraction. Clearly, the use of orthographically constrained words will facilitate this information extraction and it should not be done with single letter arrays. Furthermore, with reading disabled children, as one study showed, a systematic cognitive search must be employed to examine the periphery.

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